Risk Factors for Catastrophic Limb Injury incurred during racing for Venezuela's Thoroughbred racehorses 2000-2011

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ABSTRACT

Catastrophic musculoskeletal injuries (CMIs) are the major cause of fatalities for racehorses. The main goal of this study is identify the risk factors for the age of limb CMI during racing in Venezuela. The data included all the Thoroughbred racehorses with limb injuries attended for the veterinary team from January 2000 to May 2011. Survival analysis for discrete time data was used to establish a model for the hazard function. Specifically we assume a clog-log model related to the hazard with the covariates. The statistically significant covariates associated with limb CMI were: pre-existing pathology, number of races, and race length. Having a pre-existing pathology double the risk of limb CMI. Higher number of races and running long or medium-length races decrease the risk of limb CMI.

INTRODUCTION

Injuries and fatalities have been described in Thoroughbred racehorses for many years, with concern for different etiologies. Musculoskeletal injuries are a major cause of Thoroughbred racehorse fatalities worldwide. The proximal sesamoid bone fractures (PSBFs) are the most common type of CMI in the United States of America (USA). Other sites of fracture (metacarpal condylar, proximal phalangeal, and carpal) have been reported for different types of races in UK studies.[16,19,21] Many previous studies in the UK, USA, and Australia have reported risk factors associated with injuries, failure, fatalities, fractures, or sudden death in Thoroughbred racehorses. Overall, some of these risk factors have been: age,[2,6,9,11,16,29] sex,[4,7,10,11] race length, [1,4,11,13,18,19] race type,[1] pre-existing pathology,[23] season,[4,16] and number of races.[7,11] It is suggested that risk factors might differ among countries and according to race type.[4]

The main goal of this study was to identify the risk factors associated with the age to limb CMI injured Thoroughbred racehorse attended by the veterinary team, competing in flat races at the Racecourse La Rinconada in Venezuela, 2000-2011. A clog-log model for discrete-survival time data has been established using the age (in years) as a time to event variable. This model allows obtaining estimate for the effect of both, for time and for the covariates. We found that statistically significant covariates associated with limb CMI were: pre-existing pathology, number of races, and race length. Specifically, having pre-existing pathology double the risk of limb CMI, while higher number of races and running long or medium-length race decrease this risk.

MATERIALS AND METHODS

Racecourse

The Racecourse La Rinconada is located in Caracas at 10°30′N 66°58′W. Venezuela is a tropical country on the northern coast of South America, with two very well defined seasons--rainy season (May-October) with 1,200-1,600 mm of rainfall, and dry season (November-April) 17-125 mm of rainfall--which affect the conditions of the track. This racecourse was originally constructed as a 1,600 m (1 mile) dirt oval but was later extended to 1,800 m with a 400 m straight. The track is flat, with 45° of depth level at the curves. For the Thoroughbred racehorses racing on this racecourse must be a minimum of two years. In practice, horses have an athletic life of between 2 and 7 years, and after this age, the racehorses are destined for breeding or to other racecourses of lower categories. Moreover, horses must be approved in pre-race clinical examinations (including observation of the racehorse in walking and trotting, and palpation of all of the joints of the musculoskeletal system), and must meet sanitary requirements.

All of the horses in the study were previously medicated with furosemide (250 mg) 4 hours before and with 4 grams of phenylbutazone at a maximum of 24 hours before racing, according to Rules for Equine.[26]

Definition of CMI (Catastrophic Musculoskeletal Injuries)

The post-race evaluation allowed recording of the type of injury and its location. Horses with loss of bone continuity with vascular compromise at the level of the limbs and without any possibility of surgery were classified as Catastrophic Musculoskeletal Injuries (CMIs) category and they were euthanized (http://www.aaep.org/euthanasia_guidelines.htm).

Database

Data used in this retrospective study was recorded from January 2000 to May 2011 by a team of the veterinary clinicians, including Morales A. and Villoria D., from the Animal Health Division, Department of Pathology, and Veterinary Hospital at the Racecourse La Rinconada in Venezuela. Only data for horses treated by veterinary team was available. We included in this study the 181 records corresponding to Thoroughbred racehorses that suffered limb injuries during races.

Database Sample

The data included specimen identification (microchip) and horse characteristics such as sex, pre-existing pathology, and the number of races for each racehorse, as well as race length and season. Now there are some details about this variables:

- Race lengths were categorized into short (distance 800-1,200 m), medium (distance 1,300-1,800 m), and long races (distance 1,800-2,400 m).
- Pre-existing pathologies were defined as injuries that did not show tenderness, were not warm to the touch, and did not show lameness on walking and trotting.
- The recorded pathologies were: degenerative joint disease, osteoarthri-

Table 1. Descriptive statistics of used covariates in the cloglog model. Counts and percentages are reported for categorical variables; median and range are reported for race number. Total sample size = 181

Covariates	**Time (Age in years)**						
	2 year	**3 year**	**4 year**	**5 year**	**6 year**	**7 year**	**total**
Gender							
Female	33 (18.2)	31 (17.1)	21 (11.6)	13 (7.2)	6 (3.3)	5 (2.8)	109 (60.2)
Male	25 (13.8)	16 (8.8)	13 (18.1)	11 (6.1)	3 (1.7)	4 (2.2)	72 (39.8)
Season							
Dry	27 (14.9)	19 (10.5)	12 (6.6)	11 (6.1)	4 (2.2)	3 (1.7)	76 (41.9)
Rainy	31 (17.2)	28 (15.5)	22 (12.2)	13 (7.2)	5 (2.8)	6 (3.3)	105 (58.1)
Race length							
Short	41 (22.6)	20 (11.0)	12 (6.6)	3 (1.7)	1 (0.6)	2 (1.1)	79 (43.6)
Medium	14 (7.7)	20 (11.0)	17 (9.4)	14 (7.7)	3 (1.7)	4 (2.2)	72 (39.8)
Longer	3 (1.7)	7 (3.9)	5 (2.8)	7 (3.9)	5 (2.8)	3 (1.7)	30 (16.6)
Pre-existing pathology							
Without	41 (22.7)	41 (22.7)	24 (13.3)	13 (7.2)	5 (2.7)	3 (1.7)	127 (70.2)
With	17 (9.4)	6 (3.3)	10 (5.5)	11 (6.1)	4 (2.2)	6 (3.3)	54 (29.8)
Race number	3 (1-8)	8 (1-14)	12 (3-25)	21 (8-29)	16 (11-29)	27 (19-37)	

tis, chronic tenosynovitis, and chronic desmitis.

As previously mentioned, there are the dry and the rainfull seasons in Venezuela. During the rainy season, roads tend to become slippery, and the weather becomes hot and humid. These two seasons determine the firmness of the track, but the racing surface conditions were not officially classified. The race number was the number of races in which each horse had participated.

Statistical Analysis

Counts and percentages are reported for categorical variables (age, sex, season, race length, pre-existing pathology). The median and range are reported for race number. Distributions of the sites of the injuries and characteristics of the Thoroughbred racehorses with limb CMIs are described. The time to event was defined as the age (in years) at limb CMI. Right-censored observations correspondes to observed times for limb injured racehorses with a non-catastrophic injury.

Because age was measured in years, a discrete survival time model was more appropriate.[22] When time is assumed as a discrete variable, the hazard function is a probability.[25] In our case, it was the probability that a racehorse would experience a limb CMI in a given time, conditioned to that it had not experienced a limb CMI before. An approach for analyzing discrete survival data to establish a clog-log model for related the hazard function and a set of covariates (Author, please reword the previous sentence) We choose this model because our survival time (years) can be considered as a grouped continuous time. Moreover it proves that the clog-log model is related to the Cox-model and the exponential of the parameters can be also interpreted as Hazard Ratio (HR).[15] This is a great advantage, because HR are widely used in the survival analysis.[22,25]

In addition, from the clog-log model the hazard function could easily be estimated, for fitting the clog-log model can be used

Table 2. *Discrete-time clog-log model for time to limb CMI in Thoroughbred racehorses at the Racecourse La Rinconada Venezuela (2000-2011).*

Variable Time	**Estimate**	**Std. Error**	**z-value**	**baseline**	**p-value**
Age					
2 years	0.01346	0.26302	0.051	0.637	0.959
3 years	0.62216	0.33439	2.497	0.845	0.012
4 years	1.05526	0.42266	4.914	0.943	<0.001
5 years	2.58678	0.52641	5.752	0.999	<0.001
6 years	3.00954	0.61215		0.999	<0.001
7 years	4.80299	0.83502		1.000	
Covariates	**Estimate**	**Std. Error**	**z-value**	**HR**	**p-value**
Gender	Reference	0.20374	-0.427	0.917	0.669
Male	-0.08702				
Female					
Season	Reference	0.20107	1.471	1.344	0.141
Rain	0.29569				
Dry					
Race Length	Reference	0.22857	-2.168	0.609	0.030
Short: 800-1200 m.	-0.49549	0.31344	-1.924	0.547	0.054
Medium: 1300-1600 m.	-0.60316				
Long: 1800-2400 m.					
Pre-existing pathology	Reference	0.22260	3.060	1.977	0.002
Without	0.68116				
With					
Race number	-0.18452	0.02338	-7.894	0.832	<0.00

the standard statistical packages for dealing with binary response models but some data management.[22] (Author, please reword the previous sentence) In the results, we report the HR. The significance level was set at 0.05. The fitted model and all the results were obtained with R software, version 2.15.1, using package glme with link = "cloglog".

RESULTS

Descriptive Statistics

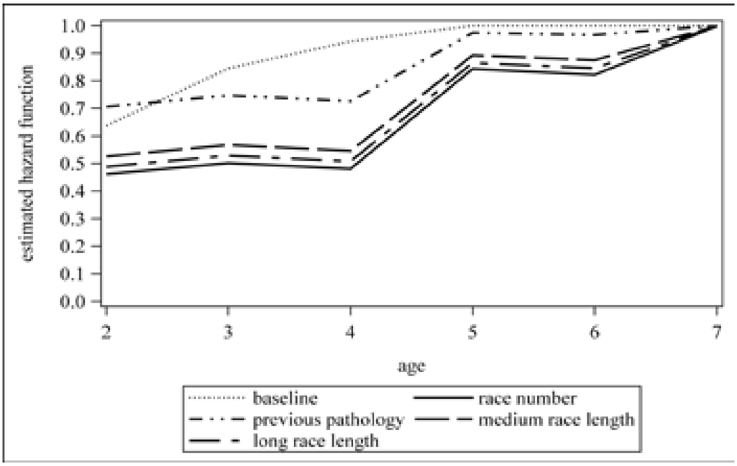
A total of 216 horses with injuries that were assessed by a veterinary team. One hundred eighty one (86.2%) showed limb injuries. The highest number of lesions were present on the forelimb 71.96%, Of the 112 horses sustaining limb CMIs (45 males and 67 females), the most common injuries were PSBF (64.3%) and third metacarpal (MCIII) (24.1%) injuries. Sixty three of those horses sustained limb CMIs in dry season and 49 in rainy season. Seven horses suffered a limb CMIs during their first races. A descriptive analysis of the covariates in the study for the 181 racehorses with limb injuries (2000-2011) is presented (Table 1).

Survival Analysis

Table 2 displays the results of the clog-log model. The model included statistically significant covariates: pre-existing pathology, race length distance, and race number. Although gender and season were not statistically significant, they were included in the model because other authors have reported them.

In the following we introduce the results concerning the effect of each statistically significant covariate in terms of hazard ratio.

Figure 1. *Estimated hazard functions with regard to race number, pre-existing pathology and race length.*



baseline includes only the age effect and it increases towards 1. When we display the hazard function including also the effect of covariates, we note that they have a common pattern; it is constant until 4 years old, and then increases. The effect of the race number has been introduced using a normalized value, computed as the mean number of races per year.

Racehorses with pre-existing pathologies had twice the risk of limb CMIs compared to with those without (e0.682 =1.98; p-value=0.002). Racehorses competing in short length races had a higher risk of limb CMI than those competing in medium and long-length races: HRshort/medium= 1/e-0.49549 = 1.642 (p-value=0.030) and HRshort/long=1/e-0.60316=1.828 (p-value=0.054). When the race number increased, the risk of limb CMI decreased. That is, HRone more race =0.831 (p-value<0.001).

The estimated hazard function over time was easily obtained from the used clog-log model. We note that the hazard function, as in the Cox model, involves two terms. One is the baseline hazard function and the other depends on covariates. In the first block of Table 2, the baseline column is, for each age, the estimated baseline hazard function. It can be obtained using the inverse cloglog transformation.[22] Note that the baseline hazard function, as one may expect, increased over time and tend to 1. This agrees with the fact that for discrete survival time the hazard function is a probability. Moreover, we note that, from 5 years old, the risk of CMI mainly depend of the covariates, because the baseline risk is 1.

Figure 1 demonstrates for each estimated hazard function race number, pre-existing pathology and race length. The

The hazard function, including only the age and the race number, represents the risk of those horses running a short race without pre-exisiting pathology (see the curve named "race number" in Figure 1).

Finally, three hazard functions are also displayed in order to see the effect of adding the other covariates (pre-existing pathology and race length). As it is displayed in Figure 1 the estimated hazard function for those horses with previous pathology is always higher than the non-baseline estimated curves (see the curve named "previous pathology" in Figure 1). For the race length, the curves are closer, being higher the curve for the medium length (see the curves named "medium race length" and "long race length" in Figure 1).

DISCUSSION

This study analyses limb CMIs in Thoroughbred racehorses at the Racecourse La Rinconada, and it also aimed estimating the effect of some characteristics of those horses sustaining these injuries. The long period 2000-2011 provided data that give the opportunity to analyze the limb CMIs of Thoroughbred in Venezuela.

In other racecourses, CMIs have been reported. One study conducted in Victoria found that, in flat races, 73% of fatalities were catastrophic limb injuries, similar to the rate reported in the UK (74%), and a slightly less than in North America (89%).[3] However, these reports were higher than the findings in the current study, in which only of fatalities were limb CMIs.

We found that most of the racehorses (71.96.%) with limb injuries had them in the forelimb. This finding was consistent with other studies reporting that the forelimbs were between 66% and 94.4% of all affected limbs.[6,13,20,29] Note that the forelimbs support 60% of the horse's weight. Thus, muscle, cartilage, tendon, and bone tissue can exceed the physiological capacity of tissue and lead to injury. Our results agreed with those obtained by Johnson et al. because we observed that the forelimbs were most affected, with a greater prevalence in the left member than the right.[13]

In the current study, the distal limb was the site most commonly affected. Similarly, this outcome was reported in another study, emphasizing that the lower limb of the horse has minimal soft tissue present, leaving the area poorly protected from injury, compared to the upper limbs and trunk.[17] These results were consistent with the findings in other studies, in which musculoskeletal injuries and fractures occurred specifically at a higher frequency in the sesamoid bone and third metacarpal.[13,16,19,21] These injuries were so severe that they ultimately led to euthanasia (similar to the findings described by Dirikolu.[17] Recently, survival analysis techniques have been used for assessing the effects of risk factors in racehorses.[11,27] In Henley et al. a continuous time as well a discrete time variable (number of races) was employed.[11] For this last variable a logit model was established.

In contrast, we consider the age of the horse in years, which defines a discrete variable for which you have established a cloglog model. In Hong Kong, the number of races ran for each horse was found to be negatively associated with the risk of injury.[28] Also in our results, the risk of limb CMI decreases with the number of races. This could indicate that more races equals increasing racing experience. Some other papers obtained results in the same direction.[7,16] Regarding race length, previous studies found that it was a risk factor related to the fatalities. In our study, the risk of limb CMI was lower in racehorses running long and medium distances than in racehorse running short distances. This result agrees with the observation that shorter races might be associated with higher speeds.[24] The higher speed for shorter distance races could be a predisposing factor that increases the risk of injury.[7] However, other studies found that longer races might be associated with a higher the risk of fatalities.[4,11,14,18,19] Pre-existing pathologic conditions could increase the risk of musculoskeletal injuries during racing or training.[5]

In this study, pre-existing pathology had a statistically significant association with age to limb CMI. This result was similar to those in a study conducted in California.[13] In addition, two common musculoskeletal injuries (metacarpal condylar fracture and severe injury to the suspensory apparatus) of the forelimb have been associated with having pre-existing palpable injuries of the suspensory apparatus of the forelimb.[6,12] Thus, even across different distributions of limb injuries, it appears that pre-existing pathology is important to future racing performance outcomes. Therefore, a prerace physical examination might determine possible pathologic conditions, thus reducing possible injuries among Thoroughbred racehorses.[6] In the present study, neither gender nor season have not been statistically significant. However we have kept in the model because earlier studies found that the risk of fatal musculoskeletal injury is different between males and females.[9,10,11]

Regarding season, earlier studies have proved that racing in summer had higher risk of breakdown than in winter.[16] In Venezuela, the weather condition directly impacts the conditions of the track in terms of area, depth and consistency, affecting the race times and maybe the risk of injuries. In summary, in this study the effect of a set of factors (race length, race number and pre-existing pathology) on the risk of limb CMI. We address using methods for analyzing discrete time survival data, given that the time variable is measured as the age of the horse at the limb CMI. The main results are that the risk of having limb CMI increases with: having pre-existing pathology, running a short race and few participation on racing (few races), To the end, we point out that authors' knowledge, the risk factors for CMI have not been investigated previously in Venezuela.

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